THE IMMEDIATE PSYCHOLOGICAL EFFECTS OF TOBACCO SMOKING

BY

DAVID JUNE CARVER

A dissertation submitted to the Board of University Studies of the Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy

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DAVID JUNE CARVER

INTRODUCTION

The work reported in this paper was done in the psychological laboratory of the Johns Hopkins University during the year 1919–1920. The reactors employed were undergraduate students in the university, with the addition of the writer and one other member of the department staff. On account of the use of students, it was impossible to control the time distribution of the reactors as thoroughly as is desirable, yet in general, the periods for each reactor were so arranged that he worked at the same hour of the day throughout, with few exceptions. Moreover, it was not possible to keep the subjects under control outside of the working hours, as should be done in ideally perfect experiments. By careful and systematic questioning, however, it was ascertained that the conditions of living and working were fairly constant, and on days when any unusual conditions of health or work had been experienced, testing was omitted.

The reactors were given specific instructions concerning the uniformization of their daily routine, and in particular, were instructed not to smoke on test days before coming up for the test. This instruction was regularly observed, except in a few cases, concerning which notes were made in the records. On intervening days, and on test days after the tests were over, "smokers" were permitted to smoke their usual amounts. "Non-smokers," of course, did not smoke at any time except in the tests in which smoking was used.

[1] The expenses of this research were in part defrayed by the Committee to Study the Tobacco Problem, but the responsibility for the planning and execution of the work, and for the conclusions, rests solely with the author and Professor Dunlap.

Prejudicing the reactors in regard to the tests was carefully avoided. They were informed that we had no expectation as to results, and also, that differences in results between smoking and non-smoking days, and between before-smoking and after-smoking results, might well occur on account of many factors other than the smoking. It was also made clear that neither the author nor the director of the laboratory had any views, positive or negative, as to the harmfulness of smoking.

After the total work on each reactor had been completed, he was questioned as to his own attitude toward tobacco using in general, and smoking in particular. Obviously, it would have been prejudicial theoretically, to ask the reactors before their work was finished. Most of the reactors professed to have no definite opinion on the matter, and no concern.

The experiments made bore solely on the immediate effect of smoking. The further, and important, matter of later effects: and of the effect of habituation to smoking, and of the cessation of smoking, are left for further investigation. Moreover, the results bear only on certain selected phases of the immediate mental effect, and do not purport to cover the whole ground. In general, the experiments bear on *efficiency* in certain mental operations, rather than on the details of those operations.

Eight types of test were used, namely: card-sorting; two sorts of mathematical work (addition and multiplication); the operation of an adding machine in ordinary listing; an association reaction (opposites); dart throwing; the steadiness test; and billiard playing. These tests are described in detail, with the results, below.

In order to obtain measurements with and without tobacco effects (if any), two procedures were adopted. In the *alternate day* procedure, the reactors were required on one day to smoke before taking the tests, on the next day to take the test without smoking, and so on alternately. In the *before and after* procedure, the experimental hour was divided into two work periods, with a "smoking" or "resting" period between. One one day the reactor smoked during the interval; on the next day he rested without smoking. These two procedures were used as a check on each other.

The amount of smoking in each test was not thoroughly standardized. Each reactor smoked either one cigar, or three cigarettes during each smoking test. The cigarettes were of a well known brand; the cigar a standard Key West, Colorado-Claro of medium weight. Cigars were smoked down to one-quarter or less; cigarettes to stubs.

While we had planned more definite standardization, we found that fine control of the tobacco itself would be meaningless. Smokers vary so much in the relative time of holding smoke in the mouth, and the depth to which it is taken in the mouth, throat, and lungs, that a mere standardization of the weight of leaf consumed would give only a misleading appearance of accuracy.

I. TESTS OF SPEED AND ACCURACY

1. Card sorting

The primary material for this test,[2] as devised by Dr. Dunlap, consisted of two packages of standard sized playing cards, each of which was punched centrally with a diamond shaped hole, the diameters of which were 2.5 cm. and 1.2 cm. respectively. These cards were punched in four ways, viz.: with the long diameter of the diamond (1) in the long diameter of the card, (2) in the short diameter of the card, (3) diagonally, from upper right to lower left, (4) diagonally, from upper left to lower right. One quarter of the cards were punched in each of these ways, and the cards were always faced the same way, in order to keep the two diagonally punched cards equal in number.

In conjunction with these cards, a receptacle consisting of a row of five stalls, was used. The cards, thoroughly shuffled by a standardized routine, were placed in the stall at the extreme left, and the reactor was required to take the cards off the stack one at a time with the left hand: then, still holding the card with the left hand, to "feel" the hole with the finger of the right hand, and after identifying it, to place it with the right hand in the proper one of the four remaining stalls.

[2] Johnson, B. Jour. Compar. Psychol., 1922, ii, 163.

The receptacle was fastened on a small table in a standardized position with regard to the reactor. A rectangular adjustable screen was so placed that the reactor could not see his hands or the cards at any time, but could see the tops of the backs of the stalls and the indicators (sample cards) fastened to each of the four stalls in which cards were to be placed. The screen allowed the reactor perfect freedom in manipulating the cards, but compelled him to sort the cards by "feeling."

The advantages in this form of discrimination test lie in the avoidance of eye-strain and other purely visual difficulties. So far as correlation of fatigue and attention is concerned, the test is at least as satisfactory as a visual sorting test under the best condition of vision.

In the "alternate day" procedure, each reactor (except reactor VI) sorted the cards five times each day, working on a ten-minute "headway." That is: the "hour" (fifty minutes) was divided into five ten-minute periods. At the beginning of each period, the cards being in readiness in the left stall, the reactor began to sort the cards. His time was taken with a stop watch from the beginning to the placing of the last card, and following this the errors were recorded, the cards reshuffled and placed in position for the next sorting, and the subject rested. Reactor VI followed the same general procedure, but sorted the cards seven times on each day.

In the "before and after" plan, the hour was divided into three "before" periods of eight minutes each: a "smoking" or "resting" period of twelve minutes, and three eight-minute "after" periods. In other words, the reactor sorted three times on an eight minute headway before smoking (or resting) and three times afterwards, on the same headway.

In all of the tables which follow, *t.* following the reactor's number indicates habitual cigarette smoker, *r.* habitual cigar smoker, *p.* habitual pipe smoker, and *n.* indicates non-smoker. Where a reactor, not a habitual cigar smoker, smoked a cigar in the test, this is indicated by (*r.*), and smoking of cigarettes in the test by a reactor not a habitual cigarette smoker, is indicated by (*t.*).

The results of the card sorting test seem to show that errors in the discrimination are increased after smoking. Every reactors, except one, in the alternate-day test, made more errors on the

TABLE 1

Card sorting: Alternate days

REACTOR	DAYS	NON-SMOKING		SMOKING	
		Time	Error	Time	Error
I *t.*	4–4	2′ 28″	1.25	2′ 34″	1.3
II *r.*	3–3	2′ 15″	1.00	1′ 57″	1.46
III *t.*	3–4	2′ 41″	0.73	2′ 30″	1.35
IV *n.* (*t.*)	5–5	2′ 42″	0.84	2′ 38″	0.84
V *n.* (*t.*)	6–6	3′ 28″	0.3	3′ 53″	0.43
VI *t.*	3–3	3′ 21″	0.52	3′ 09″	1.18

TABLE 2

Card sorting: Before and after

REACTOR	DAYS	RESTING				SMOKING			
		Before		After		Before		After	
		Average	Error	Average	Error	Average	Error	Average	Error
I *t.*	3–3	2′ 01″	0.22	2′ 02″	0.22	2′ 07″	0.11	2′ 06″	0.77
II *r.*	3–3	1′ 39″	0.88	1′ 39″	0.66	1′ 41″	0.83	1′ 40″	0.92
III *n.*(*t.*)	4–3	3′ 04″	0.33	3′ 03″	0.0	3′ 02″	0.11	3′ 06″	0.22
IV *n.*(*r.*)	5–4	4′ 07″	0.93	3′ 52″	1.4	3′ 54″	1.41	3′ 49″	2.41
V *t.*	3–3	3′ 38″	.0	3′ 34″	0.33	3′ 35″	0.11	3′ 36″	0.55
VI *r.*	3–3	3′ 27″	5.0	3′ 30″	4.55	3′ 31″	5.77	3′ 15″	7.33
VII *t.*	3–3	4′ 37″	0.22	4′ 31″	0.44	4′ 26″	0.0	4′ 07″	0.0
VIII *t.*	4–4	2′ 10″	1.25	2′ 07″	1.66	2′ 05″	1.16	1′ 57″	1.83
IX *n.*(*r.*)	3–3	3′ 29″	0.88	3′ 28″	2.22	3′ 34″	0.55	3′ 43″	1.66
X *n.*(*r.*)	5–4	4′ 19″	1.46	4′ 16″	1.46	4′ 25″	1.08	4′ 19″	1.5
XI *t.*	5–5	4′ 44″	3.74	4′ 21″	3.06	3′ 59″	3.2	3′ 55″	2.46
XII *r.*	4–4	2′ 13″	0.41	2′ 12″	1.33	2′ 14″	0.41	2′ 15″	0.33
		3′ 17″		3′ 12″		3″ 12′		3′ 09″	

smoking than on the non-smoking days. In the before-and-after test, reactors I, II, III, VI and X made the same, or fewer errors after resting than before resting, but made more errors after smoking than before smoking. But IV, V, VIII and IX, while making more errors after smoking, also made more after

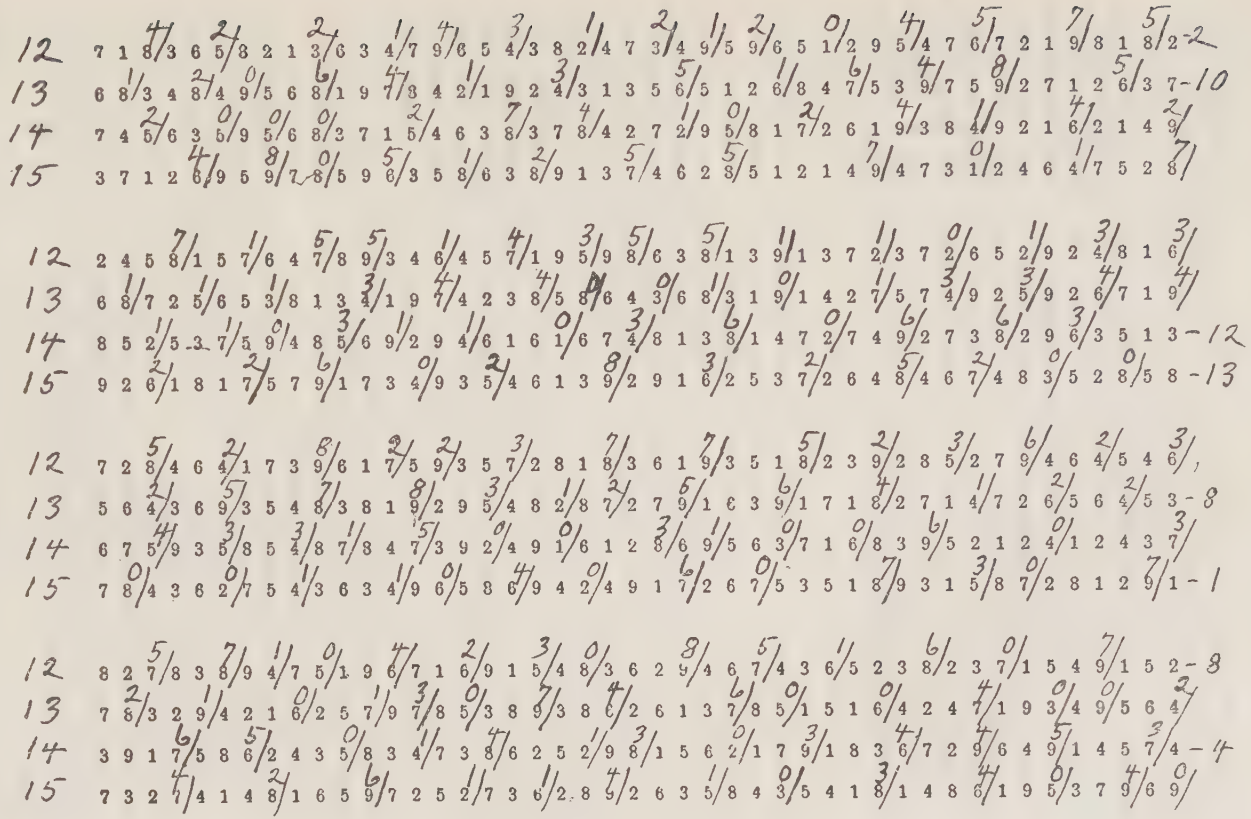
resting. Reactors VII and XII made more errors after resting, fewer or the same after smoking, while reactor XI made fewer after both resting and smoking. A comparison of the after-smoking with after-resting errors, shows no consistent variation, and no greater variation than is shown by the comparison of the before-smoking and before-resting errors.

A study of the distribution of errors within the working period, and of the variations in the sorting times through the periods, shows no systematic or uniform effect of the smoking.

On the whole, therefore, the only conclusions from these tests are (1) that there may be a slight tendency, in the case of some subjects, to increase error in discrimination after smoking, but that tests of the character of card sorting are not competent to show this clearly. (2) That if there are any effects of smoking on the speed of the discriminating reaction, tests of this character are not competent to show them. We would suspect any results of similar tests, purporting to show either favorable or unfavorable effects of smoking, to be due to faults of experimental technique, or to the employment of exceptional subjects. We consider it quite probable that, with less careful control of suggestion, and of other matters of technique, either type of result might have been obtained in these experiments. The results of these experiments showed that it was useless to continue this test. It is true that the tests as given cover the practice period, or period in the reactor's work within which improvement in speed was being made. There is, however, nothing in the detailed data to warrant the conclusion that definite effects can be discovered by the test, after the learning period is over, and the sorting process well mechanized; and we do not consider it worth while to undertake longer series on this particular test.

2. Addition test

The material used in this series of tests was the two forms of the Dunlap number work test, each consisting of a sheet containing 16 lines of 45 digits each, so arranged that each of the 9 digits (excluding zero) appeared five times in each line. At the left



ADDITION TEST. SAMPLE SHEET

of each line appeared a key-number, and the subject added digits till he obtained an amount equal to or greater than that key-number, drew a line after the last digit used and wrote above the line the difference, if the last digit used gave a sum greater than the required number. In our test the four key numbers, 12, 13, 14, 15 were used and were cyclically changed in successive sheets. On the first sheet the order was 12, 13, 14, 15, for each of the four-line groups. On the second sheet the order was 13, 14, 15, 12; on the third, 14, 15, 12, 13; and on the fourth, 15, 12, 13, 14. Two forms of this test sheet were available, making a total of 8 sheets of approximately equal difficulty, which could be used

TABLE 3

Addition test

REACTOR	DAYS	RESTING				SMOKING			
		Before		After		Before		After	
		Time	Error	Time	Error	Time	Error	Time	Error
I *n.(r.)*	4–4	9′ 53″	3.25	9′ 46″	3.25	9′ 10″	2.75	9′ 42″	5.25
II *r.*	7–7	9′ 54″	6.0	9′ 51″	3.42	9′ 18″	3.42	9′ 16″	5.0
III (*t.*)	4–4	9′ 00″	2.75	8′ 42″	2.0	8′ 57″	3.0	8′ 28″	5.75
IV *p.(r.)*	3–3	9′ 21″	5.33	9′ 10″	5.33	9′ 27″	3.66	9′ 03″	4.66
V *t.*	5–5	9′ 41″	1.0	9′ 50″	2.0	9′ 52″	1.8	9′ 43″	2.2
VI *n.(t.)*	3–3	13′ 43″	0.66	13′ 43″	2.66	15′ 14″	2.66	14′ 59″	1.66
VII *t.*	4–4	18′ 32″	2.5	18′ 48″	2.0	17′ 01″	2.75	16′ 34″	5.25
VIII *n.(r.)*	6–6	9′ 48″	3.5	10′ 01″	5.16	9′ 12″	5.16	9′ 28″	7.33

without repeating any key number with the same line. The sheets were not repeated with sufficient frequency to allow of memory from one trial to another.

Eight subjects went through this test on the before-and-after plan, working one complete sheet before, and one after smoking, or resting, on alternate days. The time required for each sheet was recorded by a stop watch.

In a smoking period, the subject smoked three cigarettes or three-fourths of a cigar, beginning the smoking as soon as he finished the first sheet. The following tables give the individual results.

The results of the addition test are given in table 3. Each of the reactors, except VII, was allowed one to three practice

days, according to the difficulty encountered, in order to become familiar with the method of addition prescribed. VII had worked several of the sheets previously in another test.

The results of the addition test, like those of the card-sorting, were not indicative of a definite effect of smoking on speed. Reactors II, III, IV, showed a decrease in time both after resting and after smoking. V, VI, and VII showed the same, or an increased time after resting, and decreased time after smoking. I and VIII showed increase both after smoking and after resting. The evidence for increase in error was, however, fairly clear. In every case, except one, there was an increase in the number errors after smoking; all except three, showed the same number, or a decrease, after resting.

3. Multiplication test

The material for this test consisted of 8 sheets, each sheet containing 16 multipliers and 16 multiplicands, arranged in two parallel columns, as in the sample sheet. The reactors were required to multiply each multiplicand by the multiplier opposite it, not copying these, but writing down in each case the three partial products, and adding them, on the sheet. After working one sheet, the reactor smoked three cigarettes and then worked a second sheet.

List 6

Multiplicands	Multipliers
771	736
435	531
914	238
566	577
187	125
146	469
295	624
359	881
194	431
554	893
986	492
823	857
973	672
732	468
123	173
246	889

Multiplication material. Sample sheet

Each of the eleven reactors worked on eight days, working one "before" and one "after" sheet each day. Six of the subjects began with sheet 1 before smoking, sheet 2 after smoking, and on the the next three days took sheets 3, 5, and 7 before smoking, and 4, 6, and 8 after smoking. The other five reactors began with sheet 2 before smoking, sheet 1 after, taking 4, 6, and 8 before, and 3, 5, and 7 after, the following three days. During the next four days the order was inverted, the first group working the even numbered sheets before smoking; the second group the odd numbered sheets before smoking. In this way each reactor worked each of the pairs both ways, and the effects of possible difference or difficulty between the sheets in a pair were neutralized.

After finishing the eight smoking days, 8 of the subjects worked four more days, resting, instead of smoking, between the sheets of the pairs. The order of sheets in this case was the same as in the "first round" for the same subject.

The results of the smoking sets are given in table 4. Reactors I to VI began with sheet 1 in the first round, with sheet 2 in the second round, while reactors VII to XI began with sheet 2 in the first round, with sheet 1 in the second.

The general results of practice are obvious, when the second round is compared with the first; although reactors V and X retrograded, the others improved. The usual increase in error after smoking is shown: the average error per sheet in the first round is 2.45 per sheet before smoking, and 3.43 after smoking, and in the second round 2.59 before smoking, and 2.97 after. The average errors for eight subjects before and after resting (not smoking), as shown by table 5, are 2.15 before resting and 1.96 after resting. If we eliminate from table 4 the three reactors (I, IV, and V) who do not appear in table 5, an increase in error is still shown after the smoking period. But still more important is the fact that nine of the eleven subjects show the after-smoking increase in error in the first round, and seven in the second; whereas only two of the eight in the non-smoking set shown an increase after resting.

TABLE 4

Multiplication test

REACTORS	BEFORE SMOKING		AFTER SMOKING	
	Time	Error	Time	Error
	First round			
I	7′ 06″	5.25	6′ 06″	5.75
II	7′ 01″	0.25	7′ 01″	0.75
III	7′ 32″	1.25	7′ 37″	1.50
IV	6′ 41″	1.75	6′ 10″	3.50
V	8′ 14″	3.75	8′ 40″	7.50
VI	7′ 37″	2.25	7′ 29″	2.50
VII	7′ 08″	2.5	7′ 01″	5.25
VIII	7′ 47″	2.25	8′ 25″	2.8
IX	7′ 16″	2.5	7′ 05″	2.25
X	7′ 10″	2.0	7′ 18″	1.0
XI	6′ 68″	3.25	6′ 14″	5.0
	Second round			
I	6′ 23″	6.25	5′ 46″	5.25
II	5′ 31″	0.25	5′ 18″	0.50
III	5′ 58″	2.50	6′ 00″	1.75
IV	6′ 36″	2.50	6′ 35″	3.00
V	8′ 06″	2.75	7′ 56″	5.00
VI	7′ 24″	1.25	7′ 13″	2.00
VII	5′ 56″	3.25	6′ 06″	3.25
VIII	6′ 51″	2.75	7′ 11″	4.50
IX	5′ 55″	1.25	6′ 17″	1.25
X	7′ 17″	1.50	7′ 32″	2.25
XI	5′ 55″	4.25	5′ 34″	4.00

TABLE 5

Multiplication test

Without smoking

	TIME	ERROR	TIME	ERROR
II	5′ 23″	2.5	5′ 19″	1.25
III	6′ 24″	1.0	6′ 27″	0.75
VI	7′ 03″	0.25	6′ 57″	1.50
VII	5′ 46″	4.25	5′ 57″	2.75
VIII	6′ 24″	2.25	6′ 18″	3.0
IX	5′ 39″	2.50	5′ 32″	2.50
X	6′ 44″	2.25	6′ 37″	1.75
XI	6′ 02″	2.25	6′ 05″	2.25

As for the effect on speed, the indications are less clear. Six of the eleven reactors show an increased speed after smoking in the first round, four show decreased speed, and one shows no change. In the second round, six show increased speed, and four show decreased, although in one case the gain is only one second, and in another the loss is only two seconds. Two who gained in the first round lost in the second, and one who lost in the first round gained in the second.

4. Adding machine test

The card-sorting, addition, and multiplication tests required the reactors to aim at speed, and also at accuracy of rather complicated coördinated reactions, failure in details of which might lead to error. It is highly desirable to use also tests in which the reactions may be made more mechanical, requiring less careful discrimination on the one hand, and less precise adjustment of action on the other. The operation of the Burroughs Adding Machine in plain listing seems to offer possibilities of such a test; and in order to try this out, two reactors who had already acquired facility in operating the machine were put at work on the before-and-after plan. Both reactors were "occasional smokers," and both smoked cigars in this test.

The Burroughs was electrically driven, so that no labor other than pressing buttons was required. The material to be added consisted of the Johns Hopkins four place addition sheets,[3] ninety sheets of which, each sheet containing merely four place numbers, all sheets of equal difficulty, have been worked out.

The sheets were arranged with the ninety numbers in a single column, separated by spaces into six groups of fifteen numbers each. The reactor was required to subtotal each group, and total the whole. The sub-totaling provides a rapid method of checking for error. Time was taken for the whole sheet.

In this test, reactor I worked three sheets before smoking or resting, and three after. Reactor II worked two sheets before and after. Smoking and non-smoking days alternated as usual.

[3] Norcross, W. H. Jour. Compar. Psychol. 1921, i, 321.

Reactor I worked nine days, five smoking and four non-smoking. His average time for a sheet on the smoking days was 4′ 22″ before smoking, 4′ 18″ after smoking. On the non-smoking days his times were 4′ 22″ before resting and 4′ 20″ after resting.

Reactor II, on five smoking and four non-smoking days, worked only two sheets before and after smoking or resting. His average times were 3′ 41″ before smoking and 3′ 36″ after: and 3′ 38″ before resting and 3′ 33″ after. Nothing was shown by these tests concerning tobacco effects on speed, and the results were so uniform that we did not think it useful to continue further with those subjects. The test is, however, worth trying on a larger scale, with subjects who have had no previous training on the machine, so that the effects (if any) of tobacco in the learning period could be compared with those in the later period when the process has become more nearly automatic.

The error in the listing of the numbers averaged, per sheet: for reactor I, 1.66 and 1.83 before and after smoking, and 0.75 and 1.25 before and after resting; for reactor II, 1.08 and 0.66 before and after smoking, and 0.75 and 0.59 before and after resting. In that case, then, the tendency towards increase of error, after smoking, shown in the previously described tests, does not occur. This is an important point, which is quite compatible with the difference between the adjustments required in this test and the card-sorting, multiplication, and addition tests, if we assume that the primary mental effects of smoking are a lessening of the integrative action of the neurons.

The adding machine test, it is obvious, should be carried out on a large scale, for comparison with other tests. The other work of the present survey precluded entering upon this phase of the work on a scale large enough to be useful, hence it was laid over for the time being.

5. Association tests

An important part of our plan included the attempt to find the influence, if any, of smoking upon the "association of ideas." This work, of course, must cover many phases, including the formation, as well as the "reproduction," of associations. As a

point of departure, we took up the problem of *controlled associative recall* with seventeen reactors, using the Dunlap chronoscope and voice keys for measurement of the reaction times.

The type of reaction control was that of *opposites*. Six lists of twenty words each were used, and in each case the reactor was required to reply with the "opposite" of the stimulus word, i.e., the word of directly contrary meaning. The word-lists were prepared, very carefully, from the Loring word lists,[4] in an attempt to obtain lists of equal difficulty. The results show, however, that we did not succeed.

Each of the seventeen reactors worked three days, all three being "smoking" days, on which the subject was given one list of words before and one after smoking. Non-smoking days were not used, because it was not considered advisable, at the start, to attempt the construction of more than six word-lists.

Eight of the reactors were given word-lists A, C, and E before smoking, and lists D, E, and F after smoking; and the remaining nine reactors were given the lists in the reverse order, that is, D, E, and F before smoking, and A, C, and E after.

After completing the set of tests on the seventeen reactors as outlined, four were again put through the series, with the same word lists, but in reverse order, so that in the second set, the reactor had, after smoking, the lists he had been given before smoking in the first round, and vice-versa.

Obviously, we had no formal basis for comparison in our results, except on the minor point of the comparative difficulty of the word lists. A change in the speed of recall after smoking *might* be assumed to be due to tobacco effects, or to the mere temporal sequence of the two lists, except in so far as our previous acquaintance with association-reaction practice and fatigue effects might enable us to decide: there are no criteria in these particular results taken by themselves. Hence, although the results were most interesting, we prefer not to present them at present, as they are not necessarily cogent to other than the experimenters.

[4] Loring, M. W. Psychobiol., 1918, i, 429–444.

We can say the following, however:

1. The word lists were not of equal difficulty, in spite of the labor spent upon them, and the most severe difficulty in the way of the further prosecution of this problem is the difficulty of constructing a sufficient number of lists of equal difficulty. To construct twelve such lists of opposites would be in itself a large job, requiring an extensive program of experimental work.

2. In spite of the difficulty of the task, the investigation of the controlled associative reaction, if it can be carried out, promises to give definite and important results, which should be compared with results of free-association tests and learning tests. We do not consider the time and energy spent in the carrying out of these preliminary tests, and in the preparation of the material, as wasted.

3. Casual tests of association are of no value whatever. Work will be entirely wasted (perhaps the results gravely misleading) unless done on an elaborate scale of materials, reactors, and technique. We should not expect a competent investigator, working on this problem alone full time with clerical assistance, to obtain any result which might be given out as other than "tentative" in less than two years.

II. TESTS OF ACCURACY ONLY

In the group of tests just described, both time and accuracy were measured, and the reactors were attempting to be both quick and accurate. In the results of those tests no effect of tobacco on speed is indicated, but an effect on accuracy is apparent. While the accuracy score would have no significance in those tests unless the reactors were working against time, the effort at speed might well have an influence on the errors. The next group of tests was designed to test accuracy only, there being no element of speed involved.

6. Dart throwing

In this test, which is modified from the Buford Johnson dart test,[5] the reactors threw the small feathered darts (made by the

[5] Johnson, B. Psychol. Rev., 1919, xxvi, 302–303.

Apex Dart Company), attempting to hit the bull's-eye of a target. The targets, which were blue-prints, had white bull's-eyes $1\frac{1}{2}$ inches in diameter, on a dark-blue ground, and five concentric narrow white rings of 6, 12, 18, 29, and 30 inches in diameter. The targets were pasted on a veritcal backing of heavy cork, 15 feet from the reactors' "toe-line" from which he threw, with the bull's-eye at approximately the level of the reactor's shoulder.

Each reactor, on each working day threw five sets of 25 darts each before smoking or resting, and five sets after smoking or resting. The darts were thrown with such rapidity of sequence as the reactor chose, with a five minute headway of the sets. That is: the throwing of the second set of 25 was commenced five minutes after the commencing of the first set; the third set was commenced five minutes after the commencing of the second set, and so on. In that way, the 125 darts before smoking and the 125 after, were in each case distributed in five groups through a little over twenty minutes, and yet the reactors threw without being hurried or retarded.

The reactors "smoked" and "rested" (without smoking) for the usual twelve minutes on alternate days between the first five sets and the second five, consuming a cigar, or three cigarettes, as indicated for each subject.

In scoring each set, a dart in the bull's-eye was scored 5, in the first ring 4, second ring 3, third ring 2, fourth ring 1, and in the fifth ring or beyond, 0. Since all darts were allowed to remain in the target until 25 had been thrown, the maximum score possible is not much over a hundred, since only three or four darts could occupy the small bull's-eye simultaneously. At the fifteen-foot throwing distance, this limit was never reached: the number of darts reaching the bull's-eye never filled it.

All of the reactors had had from two to eighteen days previous practice in dart throwing, in previous work, as indicated in the table. The results are given in table 6, in which each value is the average of five scores per day, for the indicated number of days. For reactor I, for example, the before and after scores are averages for six days, a total of 30 sets, or 750 darts before

smoking and the same number after smoking: and 30 sets also before and after "resting" on the non-smoking days: a total therefore, for the reactor of 3000 throws for the test.

The results of the dart throwing indicate that in spite of individual differences, cigar or cigarette smoking decreases accuracy. The general tendency is towards increased scores in the second sets without smoking, but towards less increase, or decrease, in the scores of the second sets after smoking. Obviously, the results are not conclusive; the variation in the initial sets (before smoking and before resting) are significant of uncontrollable variations in general condition of the reactors.

TABLE 6

Dart throwing

REACTOR	DAYS	SMOKING		RESTING		PREVIOUS PRACTICE
		Before	After	Before	After	
I *n.(r.)*	6–6	73.4	72.3	71.4	73.8 cigar	(2)
II *t.*	3–3	68.1	71.0	67.9	63.6 ct.	(10)
III *t.*	3–3	73.9	75.0	69.9	76.8 ct.	(15)
IV *n.(t)*	3–3	76.4	68.8	75.3	76.5 ct.	(13)
V *r.*	3–3	67.5	70.8	62.8	66.8 cigar	(15)
VI *t.*	3–3	77.9	76.2	73.4	77.9 ct.	(21)
VII *t.*	5–5	74.7	73.8	74.6	74.6 ct.	(3)
VIII *t.*	3–3	64.9	54.2	59.8	61.7 ct.	(18)

But the results are nevertheless sufficiently clear to enable us to say that the test is an entirely competent one, and to predict that more elaborate application of the test will show that small, but definite lowering of scores by smoking, in the case of the majority of individuals, indicates a general lowering of voluntary coördination of movements. "Individual differences," so characteristic of tobacco effects, will of course be found.

7. The steadiness test

In this test we used Dunlap's steadiness apparatus,[6] which consists of two 6-inch metal disks mounted in such a way as to be adjustable for height and angle. The front disk has eleven

[6] Dunlap, K. Jour. Exper. Psychol. 1921, iv, p. 430–432.

holes around the circumference, graduated from $\frac{1}{8}$ to $\frac{3}{8}$ inch in diameter. The back disk had a single hole the size of the largest on the front disk. In giving a test the disks were adjusted so that the center was at the height of the reactor's shoulder. The angle of inclination was kept constant in these tests. By leaving the back disk stationary and turning the front one so as to bring any desired hole over the hole of the back disk, the position remained identical throughout the several trials. A metal stylus $\frac{1}{64}$ inch in diameter was held in the hole, and contacts between the stylus and the side were recorded by the experimenter, who listened to a telephone connected in series with disc, stylus, rheostat, and the 120 volt D.C. power circuit. When used in this way, the telephone is extremely sensitive to contacts between stylus and plate.

In our tests the reactor held the stylus in each of three holes in succession for twenty seconds with twenty seconds intervening rest. This constituted a "trial." The trials were given on a seven-minute head-way, the reactor resting or smoking during the time not consumed by the test.

The time of each trial was approximately two and a half minutes, since the twenty seconds during which the reactor held the stylus in the hole was not timed from the insertion of the stylus, but from the moment when the reactor first got it in the proper position within the hole, free from the sides. A few seconds were thus lost at each insertion. Seven minutes head-way, therefore, gave an interval of approximately four and a half minutes between the end of one trial and the beginning of the next.

After the third trial each day, the subject began smoking, and continued except during the actual trials, until three cigarettes of three-fourths of a cigar, had been consumed. The rate of smoking was rapid and variable, and the smoking ended sometimes just before the fourth, sometimes just before the fifth trial ($4\frac{1}{2}$ to 10 minutes).

From seven to twelve trials were made daily by each reactor. On the first three days, holes of 12, 11 and 10 sixty-fourths of an inch were used with all reactors. Certain of the reactors were next put on holes 10, 9, and 8, but others were too inaccurate to put on these.

The instructions given each reactor were as follows:

I. Stand straight; left hand on hip.
II. Before inserting, ventilate lungs thoroughly.
III. After inserting, breathe abominally only. (Chest movements disturb arm position.)
IV. Keep eyes fixed on hole: but keep maximal attention on feelings in joints and muscles of arm.
V. Touches made while inserting or withdrawing the rod are not to be counted.

TABLE 7

Steadiness test

REACTOR	DAYS	1	2	3	4	5	6	7	8	9	10	11	12
Holes 12, 11, 10													
I *t.*	3	88	75	78	69	48	72	100					
II *t.*	2	124	128	169	206	147	172	141	134	98			
III *t.*	3	16	18	14	10	21	37	59	44	36	29	11	
IV *t.*	2	1	0	1	0	1	1	1	0	1			
V *t.*	3	17	9	11	8	14	9	9					
VI *t.*	4	2	3	0	1	5	1	1	2	0			
VII *r.*	3	13	6	6	6	4	2	6	4	4			
VIII *n.* (*t.*)	2	10	4	5	7	1	3	5	4	3	0	1	
XI *n.* (*t.*)	3	22	19	11	17	45	48	78	56	34	35	21	10
Holes 10, 9, 8													
	1	6	7	8	11	30	34	44					
VI	5	15	7	7	14	3	17	12	6				
VII	6	8	5	9	3	7	11	14	17	9	2		
VIII	6	37	51	32	40	37	32	30	31	14	7		
IX	4	58	56	62	60	91	137	184	188	62	58		

The results of the steadiness tests are summarized in table 7. The number entered for any reactor under a given trial is the total number of touches made in all three holes on that trial on the days indicated. For example: reactor I worked three days on the holes 12, 11, 10, making seven trials on each of the three days. The total number of touches on the first trials of the three days, was 88 (an average of 29.3 for the first trial of each day).

The first trials in most cases show higher values than do subsequent trials. These are adjustment-effects which are characteristic of the steadiness test, hence the first trials should be

neglected. The second and third trials give a fair estimate of the reactor's coördination before smoking. Since smoking began upon the completion of the third trial, we might reasonably look for effects of smoking (if any), at any time thereafter.

Reactors I, II, IV, VII and VIII show no clear effects in holes 12, 11, 10. Reactors III, V, VI and IX, however, do apparently show a tendency to decreased control, beginning on the first or second trial after smoking was begun. In holes 10, 9, 8, reactors V, VI, and IX again show the same tendency, while reactors VII and VIII again fail to show it. The effects may be accidental variation in some cases, but certainly are not in the 10, 9, 8 cases. It is interesting to note that one of the "non-smokers" (IX) shows the effects, but the other (VIII) does not. It can safely be said that some reactors show a tendency to decreased "steadiness" of hand (decrease in hand and eye coördination) as a result of smoking; and that there are individual variations in the restoration of the coördination.

This test was purposely made in the rough form in which steadiness tests have so often been employed. We wished to see what a rough test, under carefully controlled conditions, would show, when extended for several days. The steadiness test needs much more refined technique than is generally employed, and it is clear that a prolonged investigation with such technique will show large individual differences in tobacco effects. The effects on the different types of movement involved in unsteadiness (tremor, slow oscillations, and perhaps other types), need to be investigated in order to make this work significant. Furthermore, the effect of conditions of fatigue, attention, and emotion need to be studied in connection with steadiness, and the variations in steadiness correlated with variations in accuracy of active movement; for it is accuracy of active movement which is practically important, rather than ability to maintain a fixed attitude.

8. Billiard tests

Because of the complexity of the processes, and the nice adjustment required, in billiard shots, and the ease with which

they may be measured, it is apparent that billiards offer exceptional opportunities to study not only learning processes, but also effects of drugs and of fatigue on the accuracy of conscious reactions. We so far have made a mere beginning in applying the billiard technique to the tobacco problem, but the results have been most encouraging. Three reactors only were employed; I, the author; II, a teacher (male) of 55; III, an undergraduate. Reactors II and III had had practice in various shots on the table during the two weeks preceding the beginning of these tests.

Three standardized "set-ups" devised by J. N. Hauser, were made the basis of the tests, using ivory balls on a standard $4\frac{1}{2}$ by 9 table. These three set-ups were technically (a) a draw, (b) a follow, and (c) a dead ball shot. The reactor was required to try to make the point, and also to gather the balls as near as possible to the red ball, which was always set up as the second object ball.

The reactor was required to make ten shots on the (a) set-up; then ten on the (b), and ten on the (c). This constituted a "round." The maximal score on each shot was six; the maximal on a round therefore was 180. The balls were accurately spotted before each shot, and the "gather" was measured after the shot with a ruler. The reactor was allowed to adopt whatever rate of speed in playing suited him.

For the first set of tests, the alternate day plan was used for 12 days with all three reactors. On the "smoking" day, reactors I and II smoked each a cigar, reactor III, 3 cigarettes, before playing. In the alternate days reactors I and II did not smoke at all; and reactor III did not smoke on those days until after the billiard test. Each reactor played three rounds (90 shots) on each day of this test. The results are given in Table 8. The figures under (a), (b) and (c) in this table are averages of the daily total scores on each of the three set-ups.

After finishing the first set of the billiard shots, reactors II and III worked further for 14 and 12 days respectively on the before-and-after plan, shooting two rounds of the three set-ups before smoking, and two rounds after smoking on half of the

days; and two rounds before and after resting without smoking on the other days; the smoking and non-smoking days being alternated. The average scores for a round for reactor II were: before smoking, 138.2; after smoking, 136.2; before resting, 136; after resting, 143.3. For reactor III, the scores were: before smoking, 124.2; after smoking, 128.7; before resting, 125; after resting, 125.4.

While all three reactors made better scores on the non-smoking days of the alternate day plan, the habitual smoker (III) made better scores after smoking on the before-and-after plan, but practically identical scores before and after resting; and the non-smoker (II) made better scores after resting, but poorer after smoking. This might appear to indicate a differential effect due

TABLE 8

Billiard shots: Alternate days

REACTOR	DAYS	SMOKING				NON-SMOKING			
		(a)	(b)	(c)	Total	(a)	(b)	(c)	Total
I *n.* (*r.*)	7–7	98.4	103.8	109.1	311.4	99.4	109.8	105.5	314.8
II *n.* (*r.*)	6–6	102.5	104.5	111.3	319.1	105.0	127.5	115.3	330.8
III *t.*	6–6	116.6	119.3	119.6	355.6	122.5	124.0	121.8	363.3

to habituation, the non-smoker being deleteriously affected by the tobacco products to which his system was not adapted, while the smoker, lacking his customary smoking stimulation in the before-smoking series, was restored to his normal condition by the smoking. This hypothesis is still further suggested by the consistency of the daily averages, and the fact that for reactor III, the elimination of the first four days' scores, which are considerably lower than the scores for the remaining eight days, increases the difference between the smoking and resting scores, the scores after resting being actually lower than before resting on these days.

The uniform alternate-day effect together with certain indications from other tests, suggests that in the case of an habitual smoker, tobacco may have effect on the learning process which it does not have, or has to less extent, on the reactions after they

are fairly well learned. Of course, these few tests are competent merely to raise problems and indicate possible directions and methods of research.

GENERAL SUMMARY

1. The experimental work above reported covered a large amount of ground, and was carried on with strict regard for the conditions included in the method. The work was of the exploratory character which is the essential preliminary to more detailed investigation. On account of the nature of the work, the results are given no statistical treatment, since the calculation even of probable error in such data gives only a fictitious appearance of reliability. Certain results of value are, however, deducible.

2. It is strongly indicated that the immediate effect of smoking, both on smokers and non-smokers, is a lowering of the accuracy of finely coördinated reactions (including associative thought processes). Against this must be set, in some cases, the possible decreased accuracy of the habitual smoker when he has for some hours been deprived of his customary tobacco-combustion products, which might tend to prevent the appearance of the normal effects of smoking.

3. There is no indication that speed of complicated reactions is affected by smoking. Nor is there indication that thoroughly mechanized reactions requiring no fine motor adjustments, are affected. This would apply to the motor processes and thought processes of the man in an ordinary clerical or other subordinate business position, or those of a chauffeur. With regard to men engaged in intellectual work, and billiard players, the situation may be different.

4. If there is any effect of smoking on speed of reaction, and on efficiency in routine activity, it is clear that tests of the type used in this work; which are samples of the usual psychophysical tests, are not competent to show them. While further work with some of these tests is highly desirable, it is evident that for completion of an experimental program we must turn to the type of test devised by Professor Dunlap for use in

the Air Service, in measuring the effects of asphyxiation; since tests of this type will detect changes in mental capacity which entirely escape the older forms of test.

5. The examination of the immediate effects of tobacco smoking constitute but a small part of the necessary research program. Investigation of the remote effects; of the habituation to regular smoking; and of the immediate and remote effects of deprivation of tobacco must be made. Further, the effects on men must be compared with those on women. Finally, the effects on learning must be discriminated from the effects on habitual reaction.

6. In further research, the work must be very much more extensive in number and type of reactors, and more intensive in amount of measurement on the individual reactor, than has been in previous work. Further work such as that here reported would be a waste of time. Methods and technique must be much more refined than they have been in the past.

7. From casual measurements such as here described, we conclude that "physiological" changes (if any) due to tobacco smoking, should be investigated by modern methods, and these changes (if any) correlated with mental changes. Blood pressure changes, for example, should be carefully investigated by the simple but efficient method developed by the psychologists in the Air Medical Service, and the cause of blood pressure variations for long periods with and without smoking should be determined.

8. Finally, it is imperative that provision be made for keeping reactors under control, as regards smoking, diet, rest, mental and physical work, sex activity, etc., for long periods of time. This will be an expensive matter, but is ultimately unavoidable.

A bibliography on the effects of tobacco smoking will be presented in connection with a later investigation from this laboratory.

VITA

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